

**QUARTERLY PROGRESS REPORT
MONTANA DOT "PERFORMANCE PREDICTION MODELS"
JULY – SEPTEMBER 2003**

To:	Susan Sillick, MDT; Jon Watson, MDT
Agency:	Fugro-BRE, Inc.
MDT Contract No.:	HWY-30604-DT
Contract Period:	June 2001-May 2006
Prepared By:	Brian Killingsworth, PE, Principal Investigator
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CURRENT MONTH WORK ACTIVITIES AND COMPLETED TASKS

PHASE I

Task 1 – Literature Review

Complete. A draft memorandum, summarizing the models to be considered within this project, was submitted to the Montana DOT (MDT) in October 2001. This memorandum will be updated when the calibration and validation of the 2002 Design Guide distress prediction models are made available.

Task 2 – Review of MT DOT Pavement-Related Data

Complete. However, Fugro-BRE will continue to monitor the LTPP database and update any missing data on the test sections with time.

Task 3 – Establish the Experimental Factorials

Complete.

Task 4 – Develop Work Plan for Monitoring and Testing

Complete. The long-term monitoring plan will be revised after the initial analyses of the data are complete under Tasks 6 and 7.

PHASE II

Task 5 – Presentation of Work Plan to MDT

Complete.

Task 6 – Implement Work Plan – Data Collection

On-going activities. For the 10 sites selected initially (Condon, Deerlodge/Beckhill, Silver City, Roundup, Lavina, Wolf Point, Ft. Belknap, Perma, Geyser, Hammond), all testing has been completed. Of the four Superpave sites for which materials have recently been received, Lothair, and Baum Road have tentatively been selected for inclusion in the testing program. However, testing for these two sites will begin after a review of the results of the calibration exercise on the

initial 10 sites. The calibration exercise is completed and the review of the results has commenced.

Unbound Materials: Base/Subbase and Subgrade (Subcontractor: Fugro South, Houston, TX):

Unbound materials from the 10 sites selected in the experimental factorial (Condon, Deerlodge, Fort Belknap, Geyser, Hammond, Lavina, Perma, Roundup, Silver City, and Wolf Point) have been tested at the Fugro-South laboratory in Houston, Texas. Moisture-density curves at modified compactive effort (AASHTO T180) were derived for each of the 17 materials prior to testing. A repeated load resilient modulus test was performed for each material at optimum moisture content and maximum dry density (modified). The results of these tests have been presented in the April and May 2003 monthly reports.

HMA Cores (Subcontractor – Advanced Asphalt Technologies, Sterling, VA): All testing has been completed. There were two objectives for testing the HMA cores. The first was to obtain data for the Superpave Thermal Fracture analysis. This required low temperature creep and strength data at three temperatures. The second objective was to obtain resilient modulus data to compare with stiffness values obtained from the "Witczak et al." dynamic modulus predictive equation. All test results have been presented in previous reports except the data showing the low temperature indirect strength and strain at failure, currently being analyzed.

CTB Cores (Subcontractors – Fugro South, Inc. Houston, TX; Texas Transportation Institute, College Station, TX): The objective for testing the CTB cores was to obtain the elastic modulus of the material. However, the test protocol (ASTM C 469 - 94) requires 4 inch-diameter by 8 inch-length test cylinders to be used as test specimens. Cores more than 8 inches in length have been sent to the Fugro-South laboratory in Houston for coring and testing. Difficulties in obtaining 4 inch-diameter specimens by coring them from the center of the 6 inch-diameter cores were still encountered and are due to insufficient binder content. Of the four materials sent to Houston (Roundup, Hammond, Wolf Point and Geyser), only two—Wolf Point and Geyser—were tested. Although coring was attempted on all materials, the Roundup and Hammond cores could not be reduced to 4 inch-diameter specimens.

CTB cores of less than 8 inch-lengths were sent to the Texas Transportation Institute (TTI) laboratory to be tested for indirect tensile strength and strain at failure. The initial plan was to test the specimens in indirect tension, where test specimens are only 1-3 inches thick (6 inches in diameter). The test specimens were obtained by sawing both ends of the CTB cores that are less than 8 inches long. In order to check the correlation between the elastic modulus measured at the Fugro laboratory and the indirect tensile strength measured at the TTI laboratory, available cores for the Roundup, Hammond, and Wolf Point CTB materials were sent to both labs.

The first few indirect tensile strength tests resulted in serious damage to the instrumentation (LVDT's) mounted on the specimen and an alternative test method was sought. Fugro-BRE suggested the indirect diametral resilient modulus test. However, TTI performed seismic testing on all CTB samples with the exception of Fort Belknap. The Fort Belknap cores were very rough on the sides/ends and were only about 1.5 inches thick which made them unsuitable for testing. Although not included in the initial testing plan, density tests were performed on all CTB

materials at the TTI laboratory. The results of the seismic and density tests were presented in the August 2003 monthly report.

The modulus values obtained were highly variable with values of the coefficient of variation in most cases higher than 40 percent. The Wolf Point material was tested both at TTI using the seismic method and earlier at Fugro South using the elastic modulus test protocol. The disagreement can be explained by variability in the material and by variability due to the test method. However, the extent to which each of these components affects the measured modulus value is unknown and the confidence in the estimated modulus value is rather low. Depending on the results of the calibration analyses in which these CTB moduli values are used as inputs, Fugro-BRE may ask TTI to perform diametral resilient modulus on the same samples to increase our confidence in the results of the seismic testing.

Backcalculation of Deflections: The first round of deflection tests have been backcalculated and summarized. In addition, the second round of deflection testing has also been backcalculated utilizing the same pavement structure information as the Round 1 data. Using the backcalculated modulus values, the pavement structure was modeled as a linear elastic layered structure in ELSYM 5 and the states of stress in each layer were estimated under a load of equal magnitude with the one used by the Falling Weight Deflectometer (i.e., 9,000 lbf.). For unbound materials, the resilient modulus at the estimated states of stress was predicted using the 2002 Design Guide stress-dependent model. For the surface layer, the lab-measured resilient modulus values were used to develop a predictive model for resilient modulus as a function of air voids and temperature. The model was used to predict the lab M_R value at the temperature at which the FWD measurements were taken. Comparisons of the laboratory-derived values with FWD derived values were provided in the April and May 2003 monthly reports. A further analysis of these comparisons is underway for the Task 7 calibration.

Superpave Supplemental Sites: The project team has received a second shipment of samples from sites constructed with Superpave-designed hot mix and sampled by MDT during the time of construction. The purpose of adding these sections will be to incorporate pavements constructed with current MDT mixture design procedures. A testing plan will be developed when the review of the calibration results for the initial ten non-LTPP sites is completed.

Field Investigation Report: A field investigation report has been completed by the project team and includes a summary of the distress surveys, field sampling results (cores, borings, and other geotechnical information), FWD deflections (Round 1 only), and longitudinal profiles from each of the supplemental sites.

Supplemental Data: Fugro-BRE contacted Dr. Vince Janoo and obtained a copy of the seasonal data and draft report entitled "Performance of Montana Highway Pavements During Spring Thaw." These data will be used in analyzing the response and performance data that were monitored and obtained from other test sections.

Task 7 – Data Analyses and Calibration of Performance Prediction Models

The objectives of this task are to demonstrate the calibration technique required to develop and maintain the various model calibration coefficients that will be used by the department both now and in the future. As discussed with the MDT, four major distress types were considered in the experimental plan and thus require prediction models and calibration coefficients. These include fatigue cracking (both surface initiated and bottom initiated surface cracks), thermal cracking, rutting or permanent deformation, and ride quality.

The project team is currently awaiting release of the AASHTO 2002 Design Guide information, expected by the end of 2003, before attempting any calibration of these models. However, the calibration technique (or the specific steps required to determine calibration coefficients) was demonstrated to MDT utilizing models similar in nature to the AASHTO 2002 Design Guide models. The project team made a presentation to MDT on August 14, 2003, which included a progress report, findings, and an illustration of the calibration exercise for the Silver Spring test section.

Calibration Exercise for 10 Non-LTPP sites: An initial calibration exercise was performed for the 10 non-LTPP experimental sites: Condon, Deerlodge, Fort Belknap, Geyser, Hammond, Lavina, Perma, Roundup, Silver City, and Wolf Point. Material test data together with historical traffic and climatic data were used to predict the performance of these sites in terms of fatigue cracking and rutting in the asphalt concrete layer and rutting in the base and subgrade layers. The predictions are compared to results of the two distress surveys available for these sites (June 2002 and June 2003) and to the rutting measurements taken in October 2001. The summary tables obtained at the end of each analysis are presented in Tables 1 through 10.

Table 1. Condon

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	50,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.17	Leahy 0.060
	Base	03-Jun-03	50,000	in	?	2002 DG Model 0.000
	Subgrade	03-Jun-03	50,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 2. Deerlodge

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 ?
		01-Jun-03	300,000	%	0	<10 >37
Rutting	AC	01-Oct-01	?	in	0.03	Leahy 0.158
	Base	03-Jun-03	300,000	in	?	2002 DG Model 0.002
	Subgrade	03-Jun-03	300,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 3. Fort Belknap

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	65,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.12	Leahy 0.003
	Base	03-Jun-03	65,000	in	?	2002 DG Model 0.000
	Subgrade	03-Jun-03	65,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 4. Geyser

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	20,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.016	Leahy 0.009
	Base	03-Jun-03	20,000	in	?	2002 DG Model 0.000
	Subgrade	03-Jun-03	20,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 5. Hammond

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	100,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.088	Leahy 0.014
	Base	03-Jun-03	100,000	in	?	2002 DG Model 0.000
	Subgrade	03-Jun-03	100,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 6. Lavina

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	90,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.166	Leahy 0.011
	Subgrade	03-Jun-03	90,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 7. Perma

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 ?
		01-Jun-03	100,000	%	0	<10 >37
Rutting	AC	01-Oct-01	?	in	0.06	Leahy 0.078
	Base	03-Jun-03	100,000	in	?	2002 DG Model 0.000
	Subgrade	03-Jun-03	100,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 8. Roundup

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	20,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.035	Leahy 0.006
	Subgrade	03-Jun-03	20,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 9. Silver City

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	1,000,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.157	Leahy 0.260
	Base	03-Jun-03	1,000,000	in	?	2002 DG Model 0
	Subgrade	03-Jun-03	1,000,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Table 10. Wolf Point

Distress Method/Model:	Layer	Date	Traffic ESALs	Unit	Measured	Predicted
Fatigue Cracking	AC	01-Jun-02	?	%	0	Finn/Monismith Asphalt Institute <10 <37
		01-Jun-03	45,000	%	0	<10 <37
Rutting	AC	01-Oct-01	?	in	0.12	Leahy 0.015
	Subgrade	03-Jun-03	45,000	in	?	COE Model Asphalt Institute <0.5 <0.5

Note that the results summarized in Tables 1 through 10 are preliminary and are currently under the review by the research team.

Calibration Database Development: A first step in the process of populating the calibration and validation database was to verify which LTPP data were missing since the last time it was checked. No significant changes in the available data were found.

The status of the additional LTPP sections outside of, but adjacent to, Montana was verified. Each section was checked for sufficient data so that only those sections with adequate data are being utilized.

Structured Query Language (SQL) statements were developed for extracting the data required for model calibration from the LTPP IMS. These SQL statements will be provided to MDT so that future calibration efforts utilizing updated LTPP data may be streamlined.

A meeting was held with the database developer that included discussion of the specific requirements for the database. The database developer has restructured the database to make it more user-friendly, which will facilitate MDT using the database for further model calibration after this contract is complete. The draft database schema has been completed, reviewed and checked, and population of the database is under way. The draft database schema was included in the June 2003 monthly report.

At MDT's request, a list of all database fields and their descriptions was generated and submitted as a separate zip file along with the August 2003 monthly report. The file contains the name and description of each field and all other database properties associated with these fields.

Environmental Data: Montana climatic data is utilized in the calibration effort. Specifically, the AASHTO 2002 environmental database will be used, which will include information for Montana and surrounding regions. However, it is also recommended that MDT include additional years of environmental data (up to 20 years) to better quantify the expected environmental conditions. The project team incorporated tables into the calibration database to handle environmental data. This data includes rainfall and temperature information as well as in-situ moisture information for the appropriate environmental zones delineated in the State.

Traffic Data: A review of all the LTPP traffic tables has been re-initiated with the occasion of a new update of the LTPP database. The completeness of the data will be documented and the

need for additional traffic information will be assessed. Recommendations for the required traffic information were discussed by the project team, including Mr. Von Quintus and Dr. Mark Hallenbeck (who will continue gathering, reviewing, and assessing this data, especially in light of the initial calibration effort currently underway).

Task 8 – Final Report and Presentation of Results

No activity.

PROBLEMS / RECOMMENDED SOLUTIONS

No problems were encountered during last month and none are anticipated next month.

NEXT MONTH'S WORK PLAN

The activities planned for next month are listed below:

- Coordinate with MDT personnel on an as-needed basis.
- Continue analysis of all data collected at the LTPP and non-LTPP test sections.
- Continue with the calibration for the LTPP sites.

FINANCIAL STATUS

The Financial Summary I table shows the estimated expenses incurred during the reporting period.

The Financial Summary II table provides the total project expenditures by the Montana and FHWA fiscal years in comparison to the allocated funds for each fiscal year.

The Financial Summary III chart illustrates total expenditures by month for the project.

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Financial Summary I
Estimated Expenses for Reporting Period: Fugro-BRE

Cost Element	Last Month's Cumulative Project Costs, \$	Current Month's Expenditures, \$	Cumulative Project Costs, \$
Direct Labor	74,847	1,120	75,968
Overhead	107,031	1,603	108,634
Consultants/Subcontractors	4,050	0	4,050
ERES/ARA	15,085	6,741	21,826
Parsons -Brinckerhoff	12,093	0	12,093
SME	523	0	523
Dr. Matthew Witczak	0	0	0
Dr. Mark Hallenbeck	3,129	0	0
Travel	12,955	1,651	14,607
Testing	71,994	0	71,994
Other Direct Costs	5,800	0	5,800
Fee	30,750	1,112	31,863
TOTAL	338,259	12,228	350,488

Financial Summary II
Total Expenditures by Fiscal Year: Montana and FHWA

MONTANA DOT FISCAL YEAR			FHWA FISCAL YEAR		
Fiscal Year	Cumulative Allocated Funds, \$	Cumulative Expenditures, \$	Fiscal Year	Cumulative Allocated Funds, \$	Cumulative Expenditures, \$
6/1/2000-6/30/ 2001	15,000	*0	6/1/2000-9/30/ 2001	65,000	31,996
7/1/2001-6/30/ 2002	218,969	82,420	10/1/2001-9/30/ 2002	258,969	102,303
7/1/2002-6/30/ 2003	348,969	213,291	10/1/2002-9/30/ 2003	358,969	216,187
7/1/2003-6/30/ 2004	388,969	54,775	10/1/2003-9/30/ 2004	398,969	---
7/1/2004-6/30/ 2005	428,969	---	10/1/2004-9/30/ 2005	438,969	---
7/1/2005-6/30/ 2006	498,969	---	10/1/2005-9/30/ 2006	498,969	---
TOTAL	498,969	350,846	TOTAL	498,969	350,846

*June 2001 expenditures were combined with July 2001 expenditures.

Financial Summary III: Total Expenditures By Month

